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A Meta-Analysis of Problem-Based Learning Integrated with Ethnomathematics to Improve Children's Mathematical Literacy in the 21st Century

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Abstract
There are many applications of problem-based learning models in education, but there is no comprehensive study of the effect of problem-based learning models integrated with ethnomathematics to improve children's mathematical literacy. This study aims to analyse the problem-based learning model integrated with ethnomathematics on children's mathematical literacy in a meta-analysis. The eligibility criteria for this study are research data obtained from journals published in 2023-2025; research must be indexed by Science Technology Index (SINTA) or Scopus; Research must be relevant and report complete research data to calculate the effect size (ES) value. Data analysis with the help of JASP 0.19.30 and Microsoft Excel applications. The results of this study concluded that the 20 effect sizes analysed explained the effect of the problem-based learning model integrated with ethnomathematics on children's mathematical literacy in 21st century learning with a value of (rRE = 1.42; Z = 9.817; p < 0.001) a very strong effect size category. This finding provides positive benefits for the world of education in the implications of problem-based learning models integrated with ethnomathematics in encouraging mathematical literacy in children.

Keywords: *Problem Based Learning; Ethnomathematics; Mathematical Literacy; Meta-analysis*

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Introduction
Mathematical literacy in children plays a crucial role in equipping them with the logical thinking, analytical, and problem-solving skills needed to face the challenges of the 21st century (Pangsuma et al., 2024; Velmurugan & Davidsen, 2024; Asnur et al., 2024). In the digital era full of data and technology, children need to understand and interpret numerical information well in order to be able to make the right decisions in daily life(Malang, 2024). Mathematical literacy focuses not only on the ability to count, but also on understanding mathematical concepts that can be applied in various contexts, such as economics, science, and technology(Arrington et al., 2024; Wantu et al., 2024; Uluk et al., 2024). This skill is becoming increasingly important given the development of technology-based industries that demand human resources with the ability to think critically and adapt to rapid change. Therefore, strengthening mathematical literacy from an early age is an important foundation in creating a generation that is ready to compete in the world of work and is able to innovate in various fields (Ndiung & Menggo, 2024; Ali et al., 2024).

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Furthermore, mathematical literacy has a significant role in encouraging thinking skills in children (Wulandari et al., 2024). Many education systems still apply a learning approach that is mechanical and oriented towards memorizing formulas without providing a deep understanding of their application in daily life. As a result, children often feel that mathematics is an abstract and difficult subject, so their motivation to learn it decreases (Supriyadi et al., 2024; Leasa et al., 2024). In addition, conventional learning methods that are still widely applied in various educational institutions often focus on one-way knowledge transfer, where the teacher is the main source of information and the child only plays the role of passive recipient (Yudi et al., 2024). This approach tends to emphasize memorizing facts and procedures without giving the child enough space to explore, think critically, and develop problem-solving skills. In fact, the 21st century demands individuals to have more complex skills, such as critical thinking, creativity, communication, and collaboration, which cannot be acquired only through lecture-based learning or practice questions (Sulistyowati et al., 2024; Astuti et al., 2024). The incompatibility between conventional methods and the demands of this era causes many children to have difficulty in connecting academic concepts with their application in real life, so that they are less prepared to face the challenges of the world of work and rapid technological development (Bender et al., 2023). Therefore, it is necessary to have a learning model that can encourage mathematical literacy skills in children through the problem based learning (De Silva et al., 2023; Ngọc Lệ, 2023).

The Problem-Based Learning (PBL) learning model has a significant role in improving mathematical literacy in children by encouraging them to be active in the learning process and develop critical thinking skills (Zeng & Ruannakarn, 2023). PBL focuses on solving real-world problems that are relevant to Children' lives, so that they can understand mathematical concepts in a more in-depth and applicable way (Susanti et al., 2023; Barraza & Araujo, 2023). Through this approach, children not only learn how to solve math problems, but also understand the reasoning behind each concept and how to apply it in different situations (Kaeedi et al., 2023). In addition, PBL encourages Children to explore various problem-solving strategies, work collaboratively, and communicate their thoughts more clearly, which are essential skills in facing the challenges of the 21st century (Katsara, 2023; Drobnič Vidic, 2023).

The integration of ethnomathematics in mathematics learning has great potential to improve mathematical literacy in children by bridging abstract concepts in mathematics with familiar experiences and cultures. Ethnomathematics is an approach that links mathematics to local cultural practices and traditions, allowing Children to understand mathematical concepts in a more concrete context and relevant to their daily lives (Prasad & O'Malley, 2022; Serezli et al., 2023; Martin & Jamieson-Proctor, 2022). With this approach, Children not only learn mathematics theoretically, but also explore how mathematics has been applied in different aspects of people's lives, such as batik patterns, traditional architecture, or local trading systems (Kristiantari et al., 2022; Kelly et al., 2022; Rhonda & Gabriel, 2022; Nariman, 2021). This more contextual understanding can help children develop critical thinking, problem-solving skills, and increase their appreciation of the cultural values contained in mathematical concepts (Sumarmi & Handoyo, Budi, 2023; Sonrum & Worapun, 2023).

Ethnomathematics in learning also plays a role in increasing student motivation and involvement in understanding mathematical concepts (Cervantes-Barraza & Araujo, 2023; Maskur et al., 2020). By connecting mathematics with cultural aspects close to their lives, Children feel more involved in the learning process, thereby reducing the anxiety or fear of mathematics that often arises in conventional methods. Research conducted by Hmelo-Silver (2004) shows that PBL encourages children to develop better critical thinking, problem-solving, and conceptual comprehension skills than conventional methods. In addition, research by Savery (2015) emphasizes that PBL provides a more in-depth learning experience because children actively explore real problems and construct their own knowledge. A meta-analysis study conducted by Strobel and van Barneveld (2009) also found that PBL is more effective in improving problem-solving skills compared to traditional methods. A study by

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D'Ambrosio (2001) explains that ethnomathematics connects mathematical concepts with children's culture and daily life, so that learning becomes more relevant and easy to understand. Another study by Rosa and Orey (2011) found that the integration of ethnomathematics in the curriculum can increase children's engagement and help them understand abstract concepts through cultural experiences they have become familiar with. In addition, a meta-analysis conducted by Anwar et al. (2020) shows that the ethnomathematics approach contributes to the improvement of mathematical literacy because children can see the real relationship between mathematics and the real world.

Although many studies have explored the effectiveness of Problem-Based Learning (PBL) and ethnomathematics separately in improving children's mathematical literacy, there is still a gap in research that systematically integrates these two approaches. In addition, there have not been many studies that have used meta-analysis methods to synthesize the results of previous studies and provide stronger empirical evidence regarding the effectiveness of the combination of PBL and ethnomathematics in improving 21st century literacy-based math skills. Most of the existing studies have also not explicitly compared the effectiveness of this approach with conventional learning methods, so further analysis is still needed to assess the extent to which the integration of PBL and ethnomathematics can provide an advantage in mathematics learning. Based on this, this study aims to analyze the ethnomathematics-integrated problem-based learning model on mathematical literacy in children by meta-analysis.

Methodology

This study uses a meta-analysis approach to determine the problem-based learning model integrated with ethnomathematics on children's mathematical literacy. Meta-analysis is a research approach that evaluates previous research statistically to reach a conclusion (Tamur et al., 2020; Badawi et al., 2023; Nurtamam et al., 2023; Zulyusri et al., 2023). The meta-analysis research procedure is 1) determining the research inclusion criteria, 2) collecting data and coding, 3) analyzing the data statistically.

Eligibility Criteria

In the process of searching for data through the Google Scholar, ScienceDirect, Wiley, ERIC, ProQuest, Fronteins and Web of Science databases, the research must meet several inclusion criteria, namely from journals published in 2023-2025; research must be indexed by Science Technology Index (SINTA) or Scopus; Research must be relevant and report complete research data to calculate the effect size (ES) value. 20 studies were obtained that met the inclusion criteria published in 2022-2024 which can be seen in Table 2.

Data Collection

To obtain valid research data related to ethno-physics-based problem-based learning models to improve Children' 21st-century thinking skills collected from Google Scholar, ScienceDirect, Wiley, ERIC, ProQuest, Fronteins and Web of Science databases and frontenists. The keywords for data search are "Problem Based Learning Model", "The effect of ethnomathematics-integrated problem-based learning on children's mathematical literacy", and "Ethnomathematics"; "Mathematical literacy in children".

Statistical Analysis

Data analysis in this study calculates the effect size value of each study analyzed. The effect size value in this study is to calculate the effect of the the problem-based learning model integrated with ethnomathematics on children's mathematical literacy. According to (Borenstein et al., 2007) The stages of data analysis in the meta-analysis can be seen in (Figure 1.). Furthermore, the criteria for the effect size value in the study can be seen in Table 1.

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Table 1. Category Effect Size Value

Effect Size	Category
0.0≤ES≤ 0.2	Low
0.2≤ES≤ 0.8	Medium
ES≥ 0.8	High

Source: (Borenstein et al., 2007)

Result and Discussion

Based on the results of data search through the database, 20 studies/articles met the inclusion criteria. The effect size and error standard can be seen in Table 2.

Table 2. Effect Size and Standard Error Every Research

Code Journal	Years	Effect Size	Standard Error
PR1	2025	1.34	0.30
PR2	2023	0.67	0.31
PR3	2023	1.08	0.29
PR4	2024	2.93	0.39
PR5	2024	1.46	0.30
PR6	2023	0.83	0.33
PR7	2023	0.52	0.32
PR8	2024	0.94	0.29
PR9	2025	1.29	0.30
PR10	2025	1.19	0.40
PR11	2023	0.44	0.18
PR12	2025	0.91	0.40
PR13	2024	0.79	0.27
PR14	2024	1.04	0.49
PR15	2025	2.03	0.44
PR16	2023	1.83	0.30
PR17	2023	0.92	0.38
PR18	2024	1.52	0.45
PR19	2025	0.31	0.15
PR20	2023	0.49	0.33

Based on Table 2, the effect size value of the 20 studies ranged from 0.31 to 2.93. According to Borenstein et al., (2007) Of the 20 effect sizes, 6 studies (30%) had medium criteria effect sizes and 14 studies (70%) had high criteria effect size values. Furthermore, 20 studies were analyzed to determine an estimation model to calculate the mean effect size. The analysis of the fixed and random effect model estimation models can be seen in Table 3.

Table 3. Fixed and Random effect

	Q	df	p
Omnibus test of Coefficients Model	62.793	1	< 0.001
Test of Residual Heterogeneity	79.252	19	< 0.001

Based on Table 3, a Q value of 79.252 was obtained higher than the value of 63.793 with a coefficient interval of 95% and a p value of 0.001 <. The findings can be concluded that the value of 20 effect sizes analyzed is heterogeneously distributed. Therefore, the model used to

calculate the mean effect size is a random effect model. Furthermore, checking publication bias through funnel plot analysis and Rosenthal fail safe N (FSN) test (Tamur et al., 2020; Badawi et al., 2022; Ichsan et al., 2023b; Borenstein et al., 2007). The results of checking publication bias with funnel plot can be seen in Figure 2.

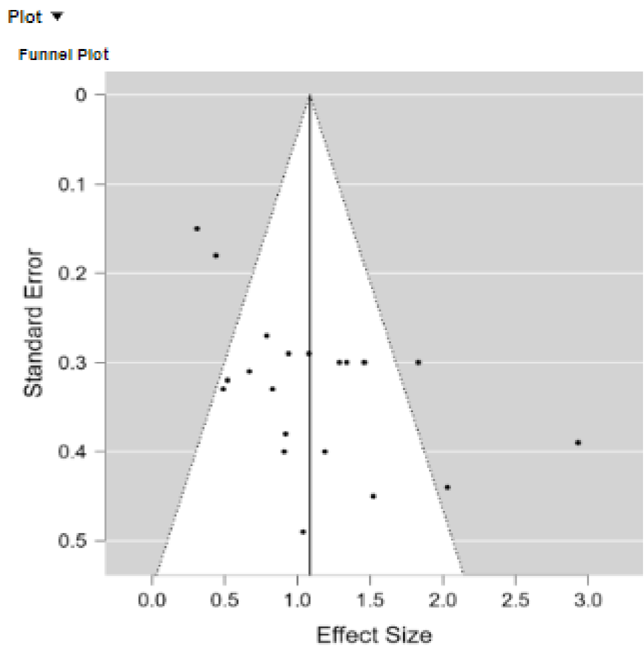

Figure 2. Funnel Plot and Standar Error

Based on Figure 2, the analysis of the funnel plot is not yet known whether it is symmetrical or asymmetrical, so it is necessary to conduct a Rosenthal Fail Safe N (FSN) test. The results of the Rosenthal Fail Safe N calculation can be seen in Table 4.

Tabel 4. Fail Safe N

File Drawer Analysis			
	Fail Safe N	Target Significance	Observed Significance
Rosenthal	1651	0.050	< 0.001

Based on Table 4, the Fail Safe N value of 1651 is greater than the value of 5k + 10 = 5(20) + 10 = 110, so it can be concluded that the analysis of 20 effect sizes in this data is not biased by publication and can be scientifically accounted for. Next, calculate the p-value to test the hypothesis through the random effect model. The results of the summary effect model analysis with the random effect model can be seen in Table 5.

Tabel 5. Mean Effect Size

Coefficient				
	Effect Size	Standard Error	z	p
Intercept	1.42	0.137	9.817	< 0.01

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Based on Table 5, the mean result of the analysis is 1.42 with a standard error of 0.137. This finding explains the significant influence of the ethnomathematics-integrated problem-based learning model on children's mathematical literacy in 21st-century learning compared to the conventional learning model ($z = 7924$; $p < 0.001$) in the effect size high category. The Problem-Based Learning (PBL) model has been widely used as an innovative approach in mathematics education because of its ability to improve critical thinking and problem-solving skills. In the context of the 21st century, mathematical literacy is not only about understanding basic concepts, but also includes the ability to apply those concepts in real life (Holder et al., 2020; Setiawan & Supiandi, 2019). PBL allows Children to learn through the exploration of relevant, real-world problems, so they can develop analytical and reflective thinking skills. Several studies have shown that this problem-based approach is more effective than conventional methods because it encourages Children to think independently, work together in groups, and find solutions with a more in-depth approach (Vina Serevina , 2018). The integration of ethnomathematics in learning allows Children to understand that mathematics is not an isolated discipline, but rather a part of everyday life that is closely related to the traditions, customs, and cultural practices of their society (Nurtanto et al., 2019; Wijayanto, 2023). This is in line with various studies that show that culture-based learning can increase Children' motivation, engagement, and understanding of the mathematical concepts taught. Thus, the incorporation of ethnomathematics in PBL not only helps Children understand mathematics better, but also provides a more meaningful context for them.

PBL and ethnomathematics can assist students in developing 21st century competencies, such as critical, creative, and analytical thinking (Sonrum & Worapun, 2023). In addition, this study also seeks to uncover the challenges and obstacles that may arise in the implementation of this model, as well as provide strategic recommendations for educators and policymakers in adopting a more contextual and innovative learning approach (Mania & Alam, 2021; Umbara et al., 2021). Thus, the results of this study can provide a deeper understanding of how the combination of PBL and ethnomathematics can be optimally implemented in the context of education. A study by Rosa & Orey (2016) shows that cultural contextualization increases student engagement compared to conventional PBL. model, as well as providing a clearer picture of its impact in various educational contexts.

Conclusion

From the results of this study, it can be concluded that there is an influence of the ethnomathematics integrated problem-based learning model on children's mathematical literacy in 21st century learning with a value ($rRE = 1.42$; $Z = 9.817$; $p < 0.001$) category of very strong effect size. These findings provide positive benefits for the world of education in the implications of a problem-based learning model that integrates ethnomathematics in encouraging mathematical literacy in children. This learning model not only helps students understand mathematical concepts in more depth, but also improves critical thinking, problem-solving, and contextual understanding skills through linkages with local cultures. The implications of these findings lead to the need for the development of a more adaptive and contextual curriculum, where learning methods that connect mathematics with cultural aspects can be better integrated in the education system. In addition, educators need to be provided with adequate training to implement this approach effectively. The results of this study also provide a basis for more inclusive and culturally based education policies, and open up opportunities for further research that explores the effectiveness of similar models in a variety of learning contexts and broader groups of students.

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